

The Mathematics of Navigating the Solar System

Gerald R. Hintz

Abstract

In navigating spacecraft throughout the solar system, the space navigator relies on three academic disciplines - optimization, estimation, and control - that work on mathematical models of the real world. Thus, the navigator determines the flight path that will consume propellant and other resources in an efficient manner, determines where the craft is and predicts where it will go, and transfers it onto the optimal trajectory that meets operational and mission constraints. Mission requirements, for example, demand that observational measurements be made with sufficient precision that relativity must be modeled in collecting and fitting (the estimation process) the data, and propagating the trajectory. Thousands of parameters are now determined in near real-time to model the gravitational forces acting on a spacecraft in the vicinity of an irregularly shaped body. Completing these tasks requires mathematical models, analyses, and processing techniques.

Newton, Gauss, Lambert, Legendre, and others are justly famous for their contributions to the mathematics of these tasks. More recently, graduate students participated in research to update the gravity model of the Saturnian system, including higher order gravity harmonics, tidal effects, and the influence of the rings. This investigation was conducted for the Cassini project to incorporate new trajectory modeling features in the navigation software. The resulting trajectory model will be used in navigating the 4-year tour of the Saturnian satellites. Also, undergraduate students are determining the ephemerides (locations versus time) of asteroids that will be used as reference objects in navigating the New Millennium's Deep Space 1 spacecraft autonomously.